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ABSTRACT

The paper explores the possibilities for applying the knowledge of artificial intelligence (AI) research to aids for the disabled. Following a definition of artificial intelligence, the paper reviews areas of basic AI research, such as computer vision, machine learning, and planning and problem solving. Among application areas relevant to the disabled are robots, expert systems, user-friendly computers, AI for microcomputers, and intelligent information-retrieval systems. Aspects of linkage between humans and computers are considered. The paper concludes with a description of four specific application areas for the disabled: perceptual aids, intelligent environment-control systems, intelligent wheelchairs, and helper robots. (CL)

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# THE POTENTIAL OF ARTIFICIAL INTELLIGENCE IN AIDS FOR THE DISABLED

JOHN J. BOYER

## ABSTRACT

This paper explores the possibilities for applying the knowledge of Artificial Intelligence research to aids for the disabled. Though many computerized aids have been developed, some of them quite sophisticated, very few of them have been "intelligent" in the sense that they make use of knowledge. Because Artificial Intelligence is still a rather unfamiliar field, this paper begins with a definition of this branch of computer science. By way of background the areas of basic AI research are then surveyed. The areas of applied research most relevant to the development of aids for the disabled are then discussed. Because disabled persons typically have "input" and "output" problems, the provision of a good linkage between human and computer is then explored, with emphasis on direct connection to the nervous system. Finally, some areas of applied research special to disabled persons are examined.

This paper concludes with suggested guidelines for determining if an aid is "intelligent".

This paper is a satellite's-eye view of an almost unexplored part of the computer usage world. A preliminary library search turned up no papers with the keywords "disabled" and "artificial intelligence." However, the territory which must be surveyed to comprehend how artificial intelligence techniques can be used to help the disabled is very large. So my survey must be very brief indeed. Research in this field is continuing at Computers to Help People, Inc.

## What is Artificial Intelligence

### 1.1 Definition

Artificial Intelligence is the attempt to program digital computers to exhibit certain types of behavior and perceptual abilities which can be regarded as "intelligent" if exhibited by a human being. These behaviors and abilities are spelled out in Section 2, which describes areas of basic AI research.

### 1.2 Boundaries

Lower Limit: Artificial Intelligence does not include numerical problems such as statistical analysis or the simulation of physical phenomena, nor does it include record-keeping functions or data processing. Upper Limit: At present this is undefinable. It is probably set by the amount of computation that can be performed between the occurrence of an event and the time when a response to it must be made.

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## Areas of Basic AI Research

### 2.1 Computer Vision

This perceptual ability would enable a computer to examine a scene with TV cameras and respond to it in much the same way as a person. At present, industrial robots guided by vision can perform some simple tasks; computers which can produce a fairly good description of a single image are operating in laboratories, but these computers require 20 minutes to analyze an image. More powerful microcomputers will, in the near future, make it possible to build vision systems that can be used on the street and in the home.

### 2.2 Understanding Written Language

Such a perceptual ability would enable a robot to accept commands typed in ordinary English, or it would enable the computer to answer questions posed by people who are not computer literate. Question-answer programs of this type are now commercially viable. Work is also proceeding on machine translation of one language into another.

### 2.3 Understanding Spoken Language

This is another perceptual ability which would make computers more accessible to noncomputer literate people. Considerable progress has been made in the recognition of words carefully spoken by a single speaker, with a pause between words. Understanding normal speech, however, is a formidable task, requiring information from disciplines as diverse as acoustics and linguistics. Laboratory machines can perform this feat with a limited vocabulary, but they are much too large and expensive for general use.

### 2.4 Modeling Human Mental Processes

Basically, this is an attempt to learn more about the only "intelligent machine" we know, the human brain. It is accomplished by formulating theories of human mental processes such as memory, problem solving, and belief formation, and then applying these theories to produce human-like responses when expressed by computer programs. This work has contributed many ideas about how intelligent computers might be built. The work has also made important contributions to psychology.

### 2.5 Machine Learning

The ability to learn seems more fundamental than both perception and behavior to any intelligent entity. It is one of the most difficult abilities to program into a computer. We want more than a machine which just passively accepts the data that are fed to it. We want a machine which can take advice and learn from experience. Some progress has been made in advice-taking machines and in programs which learn from carefully chosen examples, but the general solution remains elusive. True learning seems to require a degree of creativity that is too difficult even to apply to basic research.

### 2.6 Knowledge Representation

Though neither a behavior nor a perceptual ability, this is another fundamental area of AI research, It is perhaps even more fundamental than learning. The knowledge that the machine possesses, whether provided by the programmer or acquired through learning, must be stored in a limited memory so that it is easily and quickly available for use in reasoning and solving problems. Fundamental philosophical questions, such as "what is knowledge?" and "what is meaning?", are also involved. A great many schemes of knowledge representation have been tried. Perhaps the most popular is that of "semantic networks."

## 2.7 Game Playing

There may be readers who contend that much human game playing scarcely qualifies an intelligent behavior. In this I concur, but in games such as checkers and chess, which have received a great deal of attention in AI, the role of intelligence is undoubted. Early investigation of these games developed many of the principal AI techniques such as heuristic search. Some of the best work on machine learning was produced by Samuel (1963) with the game of checkers. Presently, chess programs can play at the grand master level, though no one expects a computer to become world chess champion any time soon.

## 2.8 Deduction and Theorem Proving

Many mathematicians and philosophers would like us to believe that this is the quintessential intelligent behavior. Although computers can use deduction to solve simple problems, they have yet to find a significant new mathematical theorem. Perhaps the most important contribution of theorem proving is the introduction of the language of formal logic into AI. This language is one of the most useful ways of representing knowledge and some of the newest AI programming languages are based on it.

## 2.9 Planning and Problem Solving

To plan is to determine a course of action before taking it. Intelligence is required both to foresee possible future events and to pick a sequence of actions to achieve a goal. Robots especially need the ability to plan, and not surprisingly, much of the planning research has been completed using real or simulated robots. Problem solving is closely related to planning because problem solving requires the discovery of a sequence of moves that will produce a desired configuration.

## 2.10 AI Programming Languages

Research in this area is concerned not so much with how computers can be made to perceive or behave as with how they can be programmed to do so. Artificial Intelligence programs are very large and complex. The main bottleneck in the wider application of AI may be the difficulty of writing these programs. The earliest special programming language for AI was LISP, developed by John McCarthy at MIT in 1960. Without it, the development of AI would have been much slower. It also contributed fundamental ideas to the broader field of computer science. Even today, LISP is used for writing many AI programs. However, it is being displaced by PROLOG (Clocksin, W. & Mellish, 1981), which is based on the language of formal logic and is more expressive.

## 2.11 Program-Writing Programs

One indication of intelligence is the ability to find things out for oneself, without having everything spelled out. Since AI programs are so difficult to write, workers in this field are naturally very interested in endowing computers with the ability to write their own programs. This would also give the machine a special form of learning, maybe even the ability to lift themselves by their own bootstraps. Programs have been written which can turn specifications written in stylized English into a complete program; they can also produce programs from examples of the desired program; but alas none of these program-writing programs seem to hold promise of relieving AI researchers of even part of their burden.

## 2.12 AI Architectures

Perception and intelligent behavior require a material substrate--a brain or, just maybe, a computer. The field of computer design is termed

"computer architecture," hence the name of this area of AI research. How does an AI computer differ from an ordinary computer? For one thing, it must be able to do many things at once. For another, it must be good at manipulating symbols instead of manipulating numbers. Perhaps most important, it must have special features that make programs written in AI programming language run as fast as possible. Many such machines have been built or attempted. The Japanese, with their "fifth Generation" computer projects (Feigenbaum, E., & McCorduck, P., 1983), are making a major effort in this area and hope to outpace the united States in what is probably the next computer revolution.

## Application Areas Relevant to the Disabled

### 3.1 Robots

The desire for robots that do more than rivet and spot weld is a primary motivation for the basic research area of planning and problem solving. The area of computer vision has also grown from this desire. In the early 1970's, Winograd (1972) wrote a program that understood English keyboard commands well enough to control a robot pictured on a TV screen. The use of English commands in a practical robot, however, must await developments in machine learning; AI architecture developments are also needed. Robots can obviously be very helpful to the motor-impaired, and can also serve as guides for the blind.

### 3.2 Intelligent Vehicles

From a computer scientist's point of view, the principal difference between a robot and a vehicle is that the latter must often follow a map. Hence, intelligent vehicles crucially depend upon the basic area of knowledge representation. On the other hand, an intelligent vehicle needs only to be told the destination; this might be accomplished by means of a simple keyboard. The utility of such a machine for the blind hardly needs to be stated. Persons with severe motor impairments would also find it useful.

### 3.3 Expert Systems

An expert system is a computer program that can answer questions and give advice where human experts are usually required to give a quality answer. The best existing expert program is probably MYCIN (Shortliffe, E.H., 1976) MYCIN can diagnose infections and make therapeutic recommendations with an accuracy equal to that of most physicians. The catch, of course, is that MYCIN knows nothing about any other kind of disease, nor does it have any bedside manner. Expert systems depend heavily upon knowledge representation. While research is under way to enable expert systems to learn from experience or observation, most of them must simply be fed knowledge by a "knowledge engineer" working with a human expert or group of experts. A possible application of expert systems for the disabled would be the prescription of aids and services. Ophthalmologists, for example, typically know little about low vision aids, and would welcome the chance to consult with an expert, even a computerized one. Expert systems will also be needed as part of intelligent, computer-aided instruction systems.

### 3.4 Intelligent Computer-aided Instruction

This description means that the program does much more than present lessons on the screen, ask for answers, and select the next lesson based on the student's responses. Such a program "knows" very little about either the course material or the student. An intelligent CAI system contains a representation of the course knowledge and a reasoning facility that makes it an expert

problem solver and problem generator in the subject matter. It can also converse with the student in somewhat the same way as a human teacher. Finally, the program builds a model of the student, so that it can conjecture what his/her misunderstandings are and take remedial action. Many connections to the basic areas of research are implicit in the foregoing description, as is the connection to expert systems. The potential of intelligent CAI programs for the disabled challenges the imagination. To cite just two possibilities, such programs might be used to acquaint blind or deaf children (or even adults) with the worlds of vision and hearing.

### 3.5 Artificial Intelligence for Microcomputers

Up to the present, most artificial intelligence programs have run on large "mainframe" computers, or at best desk-size minicomputers. If such programs are to be useful on the street, in the home, or the workplace, they must run on machines which are, at worst, desk top size, like most of today's personal computers. Texas Instruments has made a step in the right direction with its NaturalLink (Hassett, J., 1984) program, which enables the user to access the Dow Jones Information Service in English. Other companies are also introducing AI products which run on machines such as the Apple and the IBM PC. The Japanese are working night and day on both machines and programs. More efficient knowledge representations and better AI architectures are the primary needs, but advances in natural language understanding are also needed to make such systems really acceptable.

### 3.6 Intelligent Information-Retrieval Systems

The NaturalLink program mentioned in the previous section, and the INTELLECT (Hassett, J., 1984) program alluded to in Section 2.2, are examples of such systems. Similar systems could be very helpful for accessing library services, so a handicapped user could simply ask for the information he needs using his own terminal, which would have adaptations he might need, and receive this information in plain English. With advances in AI architectures, it will be possible in the near future to store a considerable library in a space the size of a filing cabinet drawer, and the user will be able to roam at will through this store of information, adding, deleting, and annotating as he chooses--all in English. This will be of great benefit to disabled students, lawyers, engineers, etc.

### 3.7 User-Friendly Computers

Basically, this is what we've been talking about in the last two sections. But user-friendly computers, computers that the user feels comfortable with which he can operate without reading the manuals, are more than this. They are also computers that can be programmed, perhaps not in ordinary English, but at least in a stylized version of English, that don't have to be told every little detail of the program. They are also computers which learn about their users so that they know what to expect under given circumstances. Like the ICAI systems discussed in Section 3.4, they might build up a model of the user's mental processes and might have some understanding of psychology. (Programs which mimic various types of psychotherapy have already been tried.)

### 3.8 Making AI Comprehensible to Ordinary Programmers

This is an important issue, because AI has developed in the hothouse atmosphere of academia. If AI techniques are to be widely applied, both the program and the programming languages in which they are expressed must be understandable to more people than computer science masters. Indeed,

they are often not comprehensible even to this elite. Much of this abstruseness is due to the use of quasi-mathematical forms of expression and to habits of convoluted thinking. AI programming is not for everyone, but simpler techniques should be within the reach of most programmers.

**The Human-computer Interface**

This section is included because disabled persons typically have "input" or "output" problems. In preceding sections, i.e., on user-friendly computers, I have discussed what might be called the "cognitive interface." Discussion of the physical link between human and computer now seems in order.

## 4.1 The Inadequacy of Present Interfaces

Although the most common human computer interface--the combination of keyboard and TV screen--has obvious disadvantages for persons with either sensory or motor impairments, it is true that with special adaptive devices a disabled person can have a better "linkage" with the world through a computer. At least a limited ability to understand speech, will be a great advance when it comes, but it will not help the nonverbal. Technology is now arriving for another type of interface, as applicable to the disabled as to the nondisabled; it will put everyone on an equal footing.

## 4.2 Direct Connection to the Nervous System

The statement has been made, and may well be made again, that the computer is the most potent mental tool ever invented. Why not, then, bypass possible inoperative organic sensors and effectors and connect it directly to the nervous system? Computers which are small enough to be implanted inside the body are already available. The chief problem is the provision of power and, of course, the actual interface. Research has been conducted at the University of Utah and elsewhere on the implantation of electrodes in the cochlea, or inner ear. A long series of experiments have been completed by Dobeel (1979) and his colleagues in which electrodes were implanted in the visual cortex of human subjects and stimulated, with encouraging results. It is my feeling, however, that this latter approach is unduly invasive and dangerous. It is better to make the connection to the peripheral nervous system which is more robust than the brain and can regenerate if a mistake is made. At present this can actually be done, though crudely.

## 4.3 Towards Symbiotic Human-Computer Systems

It is the dream of every disabled person to have free access to all information, and to control as much of the external world as his/her non-disabled counterparts. Computer technology and neurophysiology are progressing to the point that a human being and an intelligent computer can be linked into a truly symbiotic entity in which each member does what he/she/it is best capable of doing. The human has full scope for exercising imagination, intuition, and creativity. The computer has its abilities for fast calculations and for precise logical reasoning. In the case of a sensorially deprived human being, the computer would also provide enough perceptive power that the human could use his adaptive ability to learn to interpret the external world through the artificial senses. A motor-impaired person would be able to control his environment or a vehicle through thought alone. Although this concept of a human-computer team is applicable to everyone, it is quite possible that disabled persons will be among the first to put it into practice.

## Special Application Areas for the Disabled

Although the general application areas discussed in Section 3 will be of great advantage to the disabled, there are also a few applications which are unlikely to be taken up in any other content. These are discussed in this section.

### 5.1 Perceptual Aids

Two principal types of aids for the sensorially-deprived are likely to be developed; visual guidance systems for the blind and phonetic transcription systems for the deaf. The former would guide a blind or deaf-blind user safely through an urban environment, perhaps even enable him to drive a car. Formidable problems in "scene analysis" must still be overcome, but one of the greatest difficulties is conveying the perceptual information through auditory and tactile channels of limited capacity. A perceptual aid of this type is now under development at the Smith-Kettlewell Eye Research Institute in San Francisco. I am working on such a device, but taking a different approach.

A phonetic transcription aid for the deaf would monitor a conversation and produce a phonetically-spelled transcript of it in a written form, perhaps on a video monitor (TV screen), or in Braille for deaf-blind users. It would also be capable of identifying various speakers for its user. Such a device might be relatively easy to build, yet the complexities of spoken language requires some understanding of the subject matter to make an intelligible transcript. Greater advances in the understanding of spoken language are, therefore, needed before it can become viable.

### 5.2 Intelligent Environment-Control Systems

The term "intelligent" means here that the environmental control system will respond to commands in normal speech and not just the isolated words that most current systems can handle. It will learn about the needs and desires of its user, so that it will be capable of adjusting the environment without explicit directions.

### 5.3 Intelligent Wheelchairs

An intelligent wheelchair imposes more stringent requirements than your ordinary, run-of-the-mill intelligent vehicle, because of its small size and peculiar operating environment. It should be adaptive, learning how to adjust to its user; it will respond to spoken commands and it may incorporate an environmental-control center. It might also contain perceptual aids and effectors, as well as information-processing facilities such as an intelligent word processor.

### 5.4 Helper Robots

The intelligent wheelchair discussed above is practically a robot with a human user providing the majority of the control and decision-making functions. Helper robots capable of independent operation will become feasible before the general problems of robotics are solved, just as industrial robots are feasible now. Experimental machines are already in existence. A robot arm developed at John Hopkins has been helping quadriplegics feed themselves and do office work for a number of years. A guide dog robot developed in Japan has successfully guided blind users along paths marked out with special "landmarks." These devices, however, are quite unintelligent, as they lack learning ability and do not respond to natural language commands.

## Conclusions

Based on the above, I would like to propose the following guidelines for determining whether an aid is "intelligent." A device may deserve

this adjective if it satisfies one of these guidelines to a high degree, or several of them to some degree.

1. Does it have some perceptual ability, i.e., can it analyze a scene or understand human language?
2. Does it have an internal model of its user, so that it can guess his/her state of mind?
3. Does it learn?
4. Can it reason logically, drawing conclusions from premises?
5. Can it make plans?
6. Is it self-programming?

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